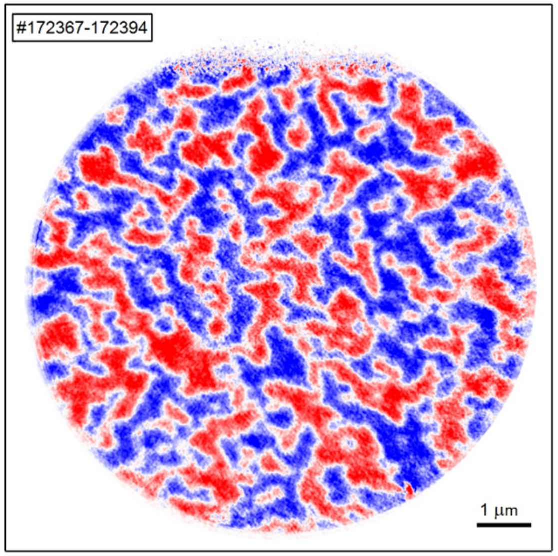
2019年度　提案書（**Web公開用**）　　作成者：　Aleksandr Kurenkov（東北大CSIS/CSRN）

研究プロジェクト名：　Correlation between antiferromagnetic and ferromagnetic domain structure in spin-orbit torque induced memristive magnetization switching.

概要：　We propose to study spin-orbit torque (SOT) switching in antiferromagnet/ferromagnet (AFM/FM) heterostructures, which have non-volatile analogue-like properties. By means of photoemission electron microscopy (PEEM) coupled with x-ray magnetic circular and linear dichroism (XMCD and XMLD) we plan to study how FM and AFM domains interact and how this explains the unique switching. First experiments, performed at the Diamond Light Source synchrotron in collaboration with Prof. Gambardella's group of ETH yielded domain patterns in FM [Co/Ni] that have never been observed before (see the Figure). We plan to actively extend this collaborative work to fully reveal what governs the switching process and how it can be tuned. For that we plan to image AFM domains simultaneously with FM ones, see switching in nanosized devices and, in perspective, perform time-resolved measurements.

コアメンバー：　Dr. Aleksandr Kurenkov (CSIS/CSRN, Tohoku University), Prof. Shunsuke Fukami, Prof. Yoshihiko Horio (RIEC, Tohoku University), Prof. Pietro Gambardella and members of his group (ETH Zürich, Switzerland), Dr. Francesco Maccherozzi (Diamond Light Source, United Kingdom)

期待される研究成果：Results of this study will improve fundamental understanding of exchange bias and SOT switching. Also, they will show a path for engineering customized AFM/FM analogue-like and binary devices for conventional and neuromorphic applications. The chosen method of PEEM XMCD/XMLD cannot be replaced with other techniques such as MOKE or transport measurements, which increases the value of obtained knowledge. Preliminary measurements of the system forecast fruitful and insightful experiments since both XMCD and XMLD contrast have been achieved in our system and domain structure could be reproducibly altered by SOT.

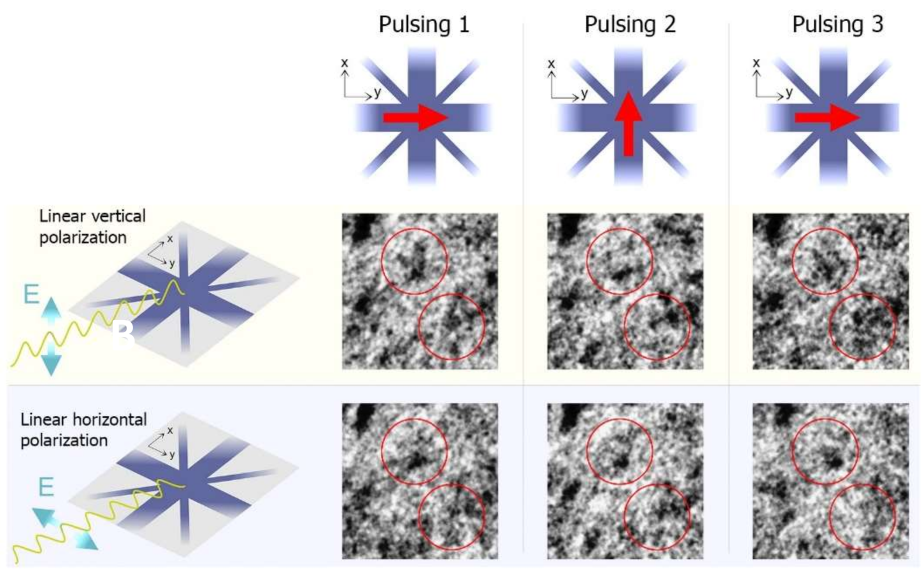


XMCD image of nonvolatile domain patterns in [Co/Ni] ferromagnetic layer, prepared on top of antiferromagnetic PtMn. This yields memristive SOT switching of AFM/FM.

研究プロジェクト名：　Correlation between antiferromagnetic and ferromagnetic domain structure in spin-orbit torque induced memristive magnetization switching.

概要：　We studied spin-orbit torque (SOT) switching in antiferromagnet/ferromagnet (AFM/FM) heterostructures which showed non-volatile analogue-like properties. By means of photoemission electron microscopy (PEEM) coupled with x-ray magnetic circular and linear dichroism (XMCD and XMLD) we studied how FM domains behave differently depending on the properties of the local exchange bias and how AFM domains could be switched in a controllable and reproducible manner by orthogonally directed trains of current pulses.

研究成果（実施状況）：We measured the spin-orbit torque switching of the Neel vector in antiferromagnetic PtMn (see figure on the left). We could reproducibly control the state of the antiferromagnetic by applying trains of 50 pulses of 50 mA in the orthogonal directions. Switching measurements coupled with XMCD allowed to characterize different areas of the ferromagnetic layer and indirectly characterize the underlying exchange bias (analysis currently in progress).



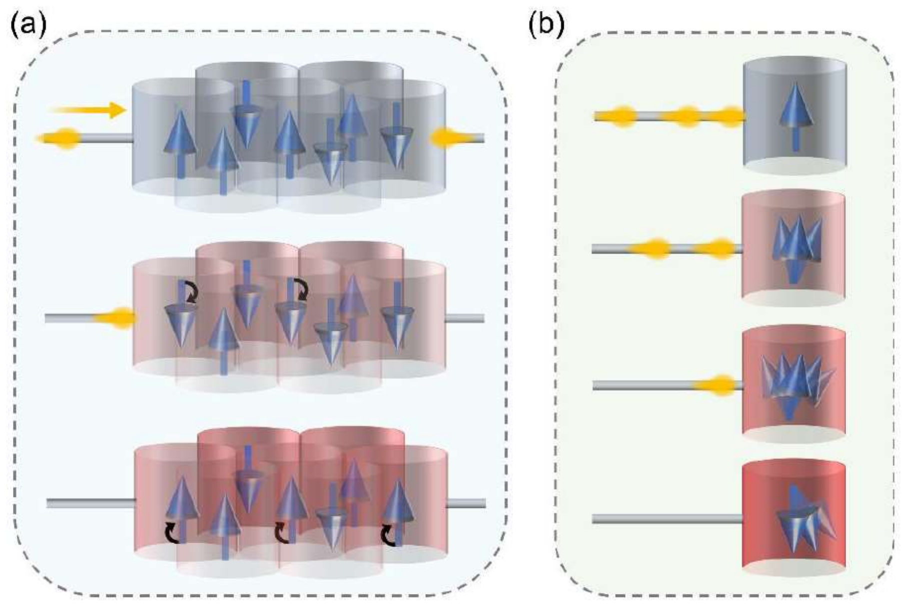
主要発表論文等：
[1] G. Krisnhnaswamy, A. Kurenkov et al., to be submitted (July 2019).
[2] S. DuttaGupta, A. Kurenkov et al., to be submitted (June 2019).

2019年度　報告書（**Web公開用**）　　　　　作成者：　Aleksandr Kurenkov（東北大CSIS）

研究プロジェクト名：　**Correlation between antiferromagnetic and ferromagnetic domain structure in spin-orbit torque induced memristive magnetization switching**

概要：　**Research of the dynamics of spin-orbit torque-driven magnetization switching in antiferromagnet/ferromagnet heterostructures for the purpose of using this non-linear dynamics for biologically plausible local computations in artificial synapses and neurons.**

研究成果（実施状況）：　**It was clarified that switching dynamics is considerably influenced by temperature dynamics that originates from Joule heating. It allows measuring time intervals between pulses because if a pulse arrives shortly after the previous one, it receives the residual heat and can produce more switching in the system. This time measuring mechanism allows reproducing operation of a biological synapse (Fig. (a)) and a neuron (Fig. (b)).**



主要発表論文等：**[1] A. Kurenkov et al., Adv. Mater. 31, 1900636 (2019).**